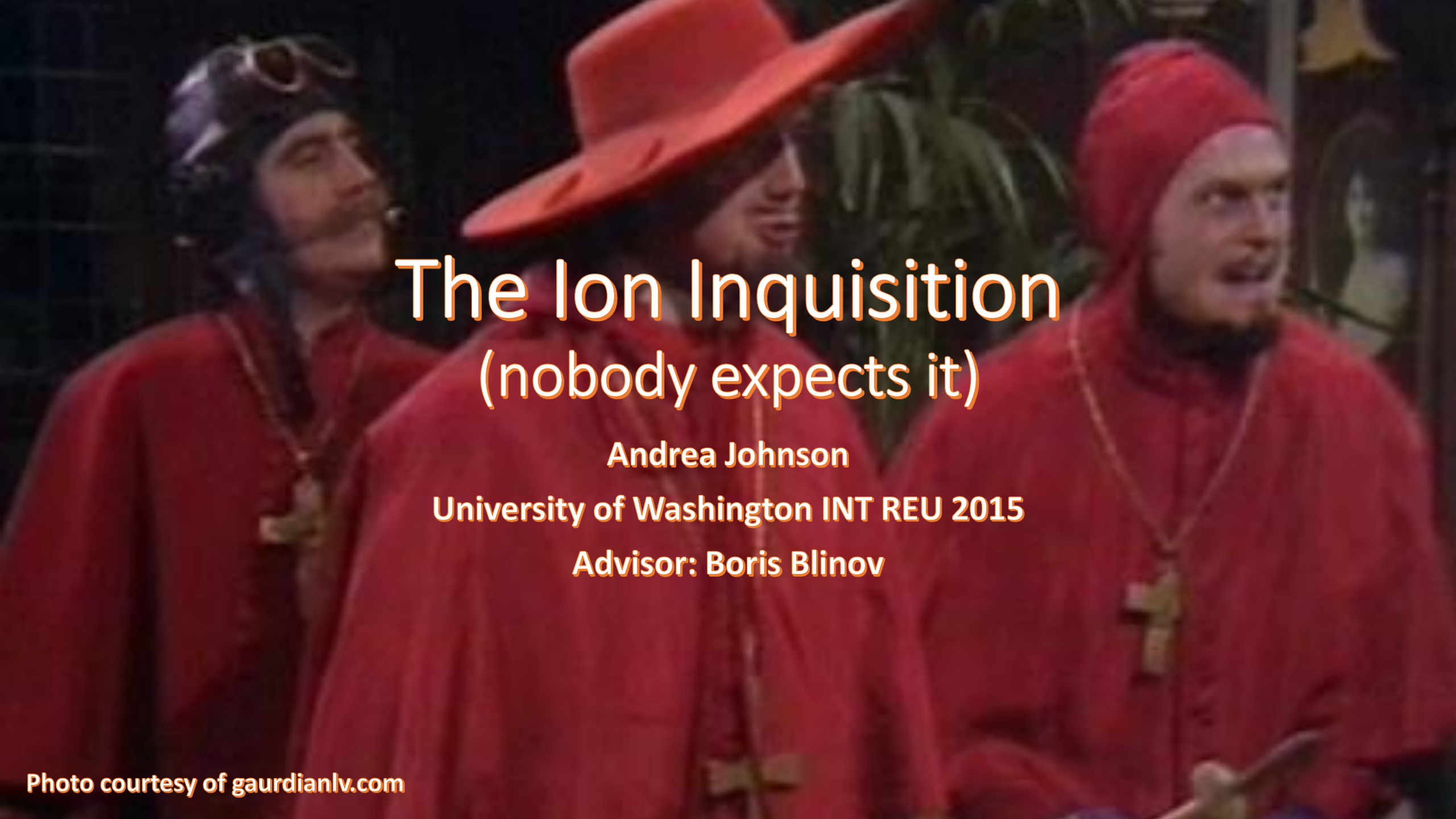

The Ion Inquisition
(nobody expects it)

Andrea Johnson

University of Washington INT REU 2015

Advisor: Boris Blinov

Photo courtesy of gaurdianlv.com

Overview

- Background
- Experiment setup
- My project
  - Barium and Ytterbium trapping
  - Rabiflops and transition scans
  - Sideband scans
  - Altered some code for scanning
- What’s next?

Coming up ->

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Why Quantum Computing

- Moore's law
  - Shor's factoring algorithm, Grover's search algorithm, etc.
  - Simulating quantum mechanical systems
  - NP vs P
- Quantum bits (qubits)
  - 2 states plus superpositions of these 2 states
  - Measurement collapses any superposition

Photo courtesy of wired.com

Ingredients for a good quantum computer

- DiVincenzo criteria (the following come directly from DiVincenzo, 2000)
  1. A scalable physical system with well characterized qubits
  2. The ability to initialize the state of the qubits to a simple fiducial state, such as |000…>
  3. Long relevant coherence[sic] times, much longer than the gate operation time
  4. A “universal” set of quantum gates
  5. A qubit-specific measurement capability

Why trapped ions?

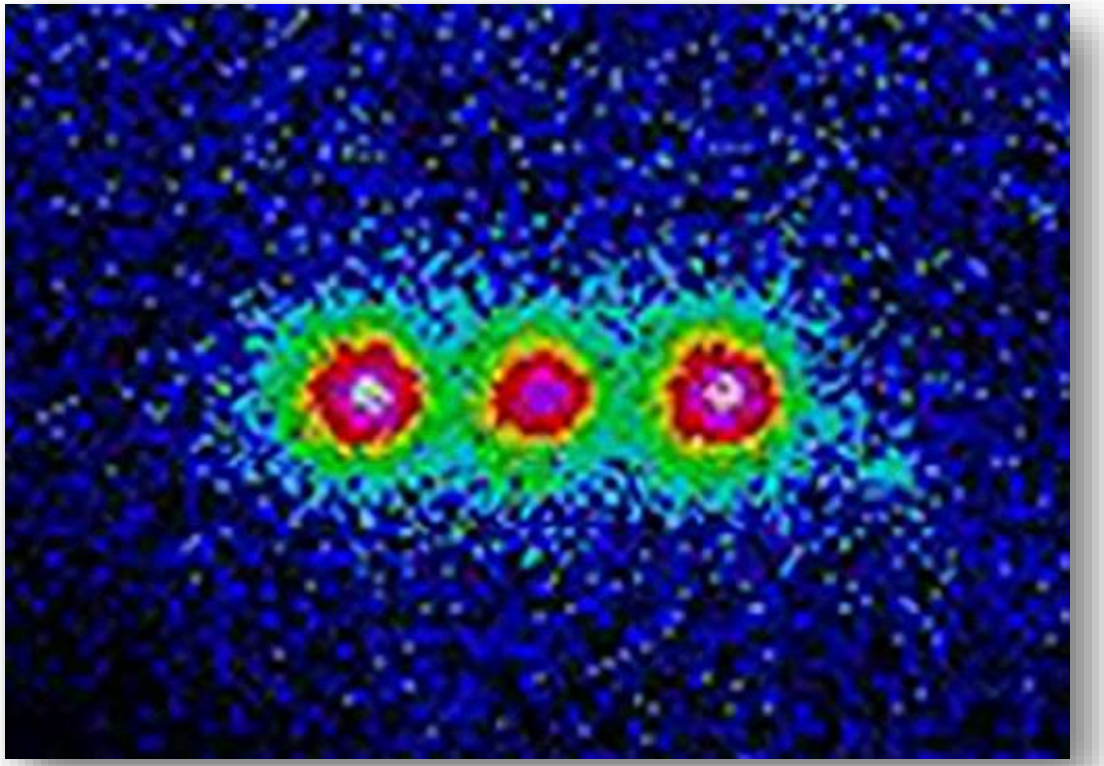

Photo courtesy of physicsworld.com

1. Energy levels act as qubits

2. (and 5) Initialization and readout can be done

3. Long coherence times

4. Entanglement and quantum gates are possible

- We are using mixed chains of Barium and Ytterbium ions

Barium-Ytterbium chains

- Ytterbium
  - hyperfine levels are used to store the quantum information
  - Less prone to be affected by external factors (magnetic field noise)
  - Longer coherence times

Barium-Ytterbium chains cont.

- Barium
  - Cooling Barium with lasers reduces likelihood of system decoherence since ytterbium stores quantum info instead
  - Used to cool ytterbium ions (sympathetically)
  - Also used for remote entanglement which can then be passed to ytterbium ions

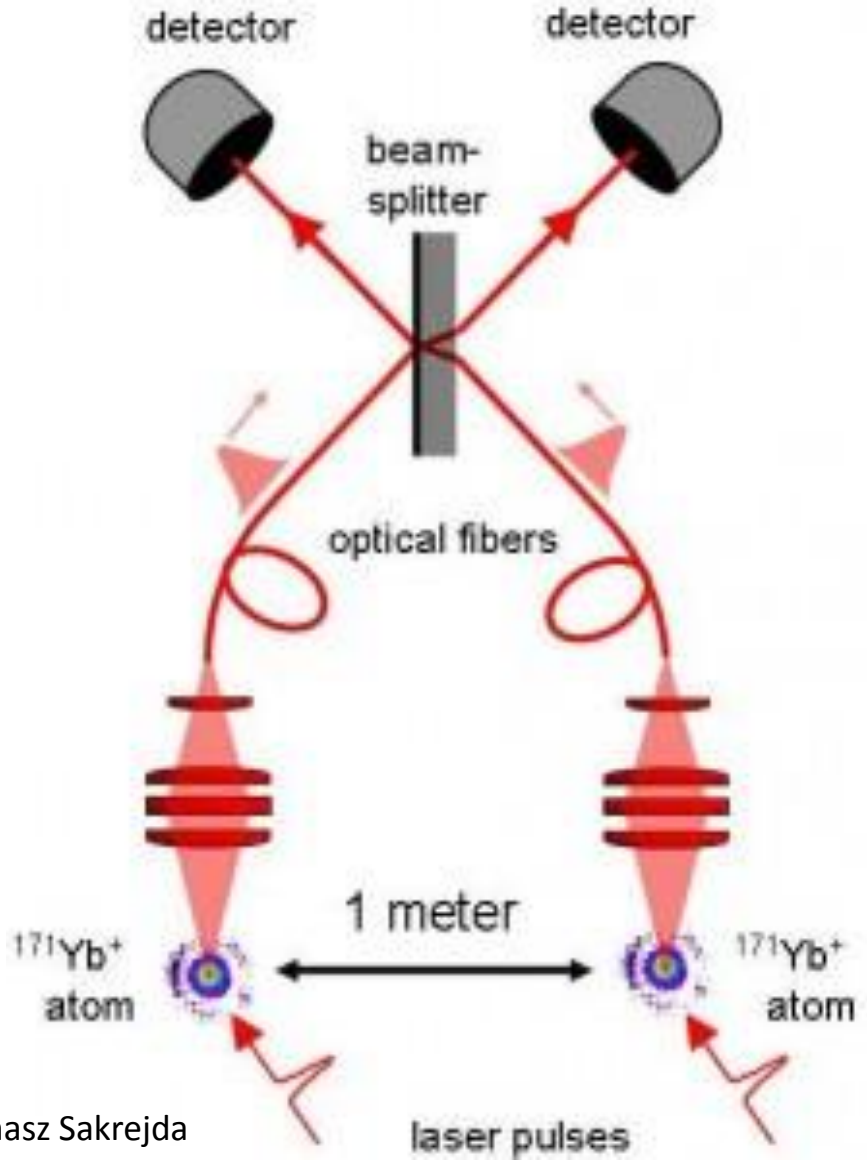

Photo courtesy of Tomasz Sakrejda

Why do we want cold ions?

- Mølmer-Sørensen gates
  - Involves changes to motional state
- Maintain chain order
  - Too hot and chain reorders

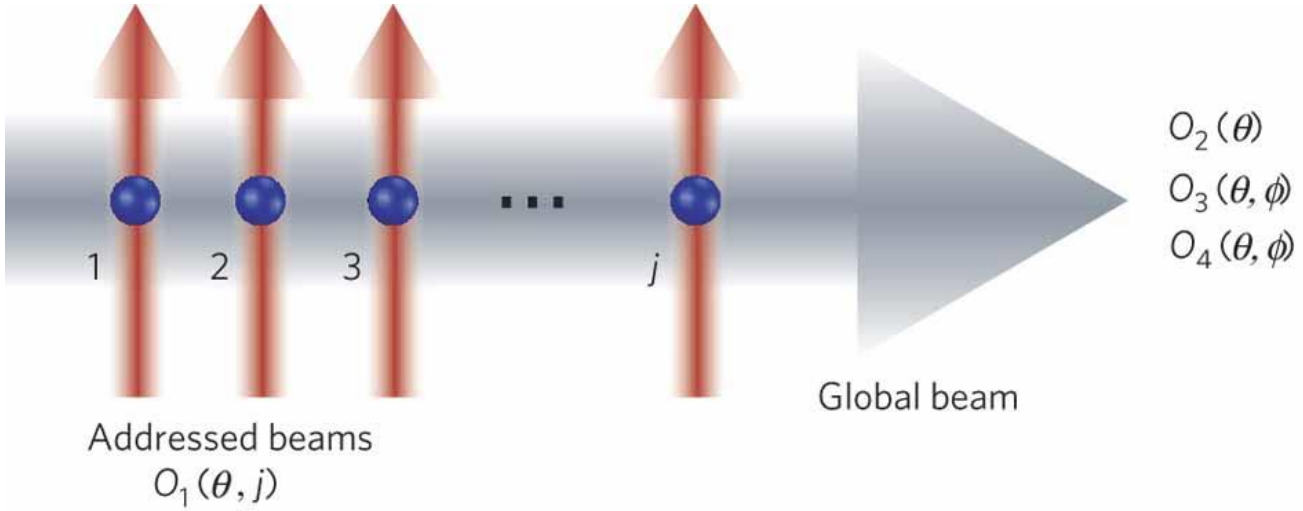

Photo courtesy of Tomasz Sakrejda

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Linear RF-Paul Trap

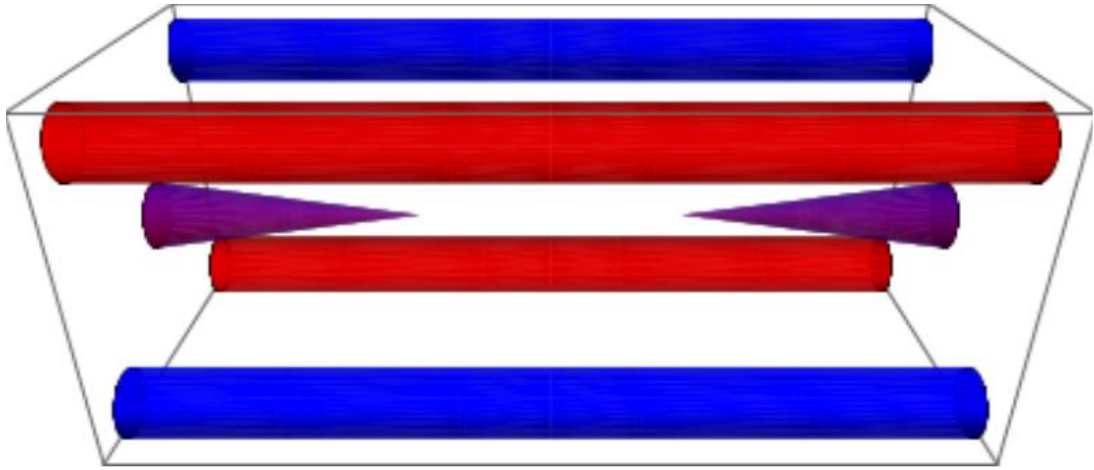


Photo courtesy of John Wright

- Radially confined by the rods
  (red has rf voltage applied, blue is ground,
  high voltage applied to purple needles)
- Axial confinement is performed by the needles
- Voltages on rods change to provide the “flapping” of the E field
  (shown on the right)
- This confines the ion in 3D

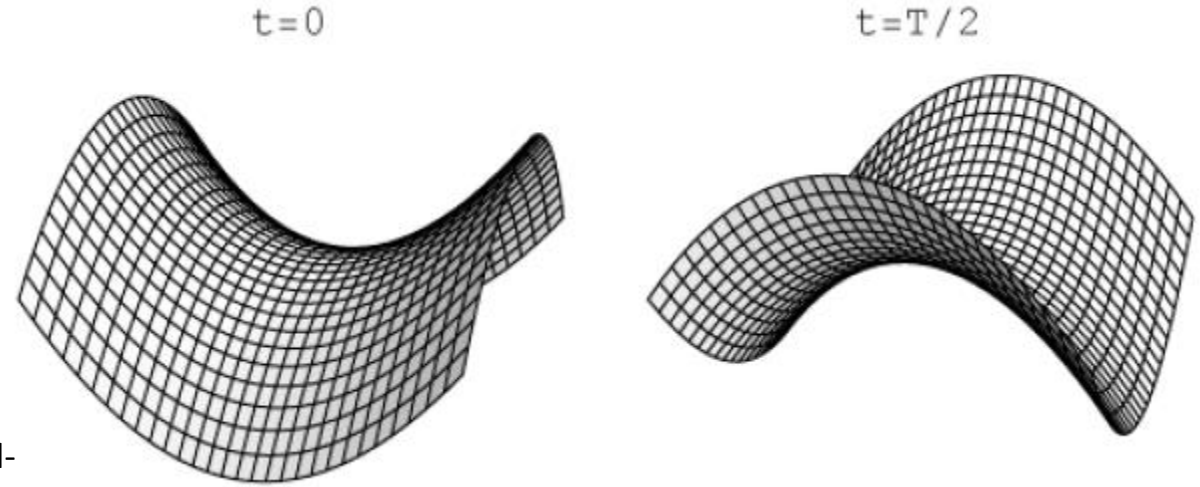
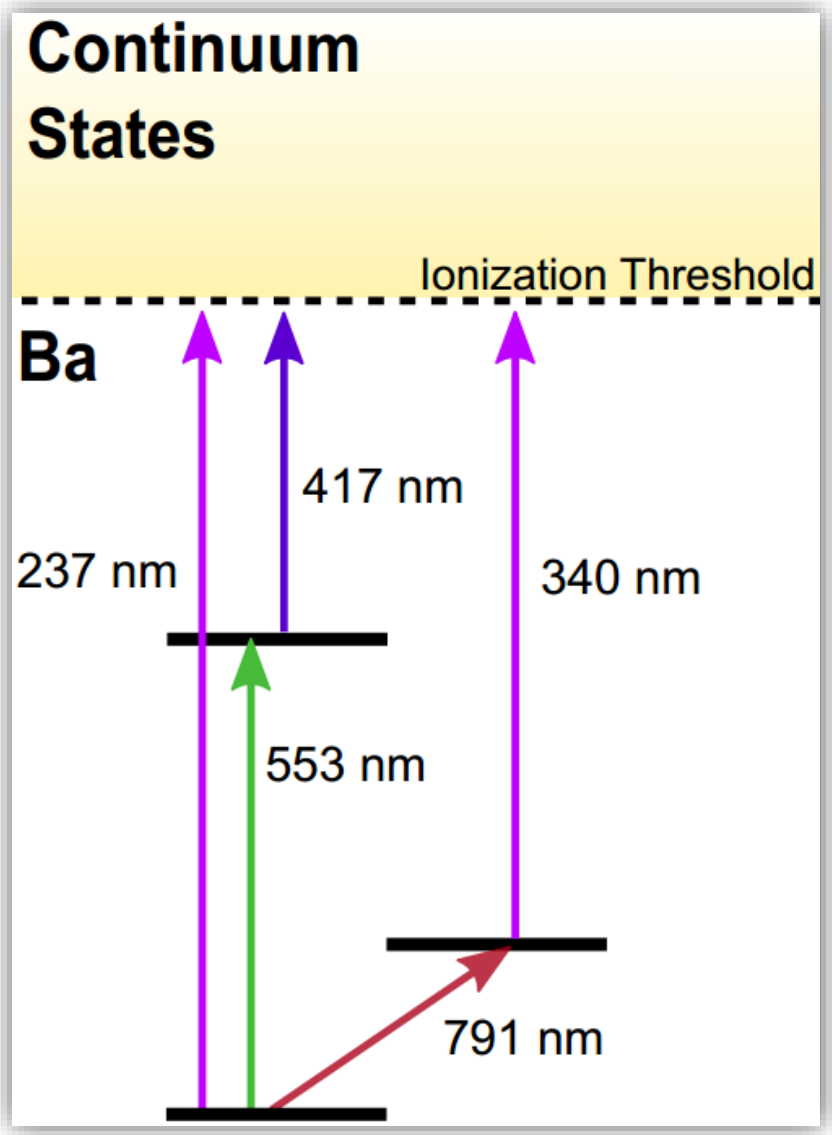


Photo courtesy of Mostafa
on http://physics.stackexchange.com/questions/82291/quadrupole-potential-generation-in-paul-traps

Photoionization

- Oven produces neutral atoms
- Drive from ground state to excited state
- Ionize with nitrogen pulses



Courtesy of Spencer Williams

Laser cooling

- We use Doppler cooling to cool our ions
  - Set our lasers to just below the transition
  - Cooling cycle (involves 493 and 650) ------->

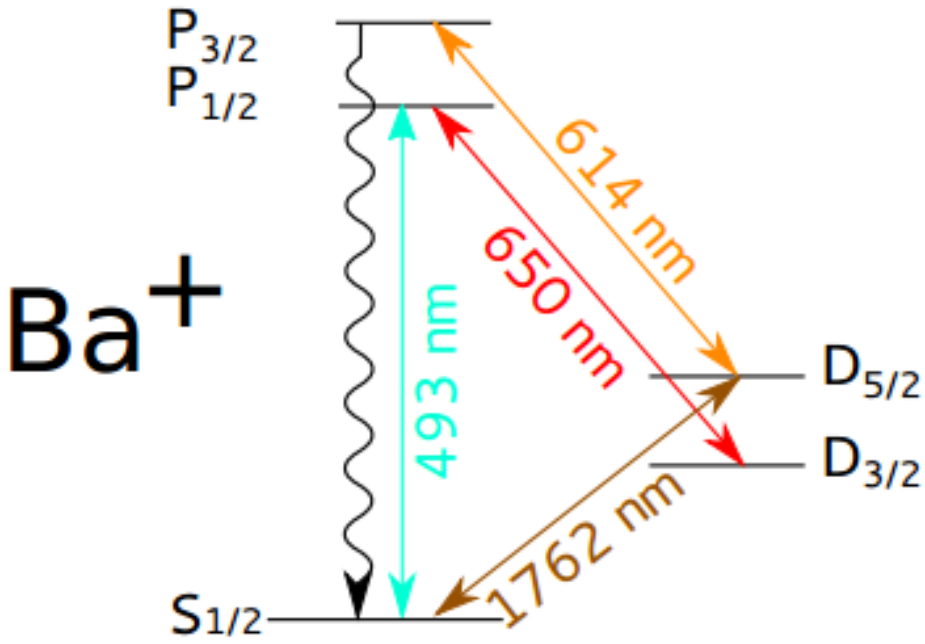


Photo courtesy of John Wright, et. al

  - Only ions moving toward laser absorb the photons (Doppler effects)
  - Ion emits photons in random directions (doesn't add momentum) -> overall decrease in momentum

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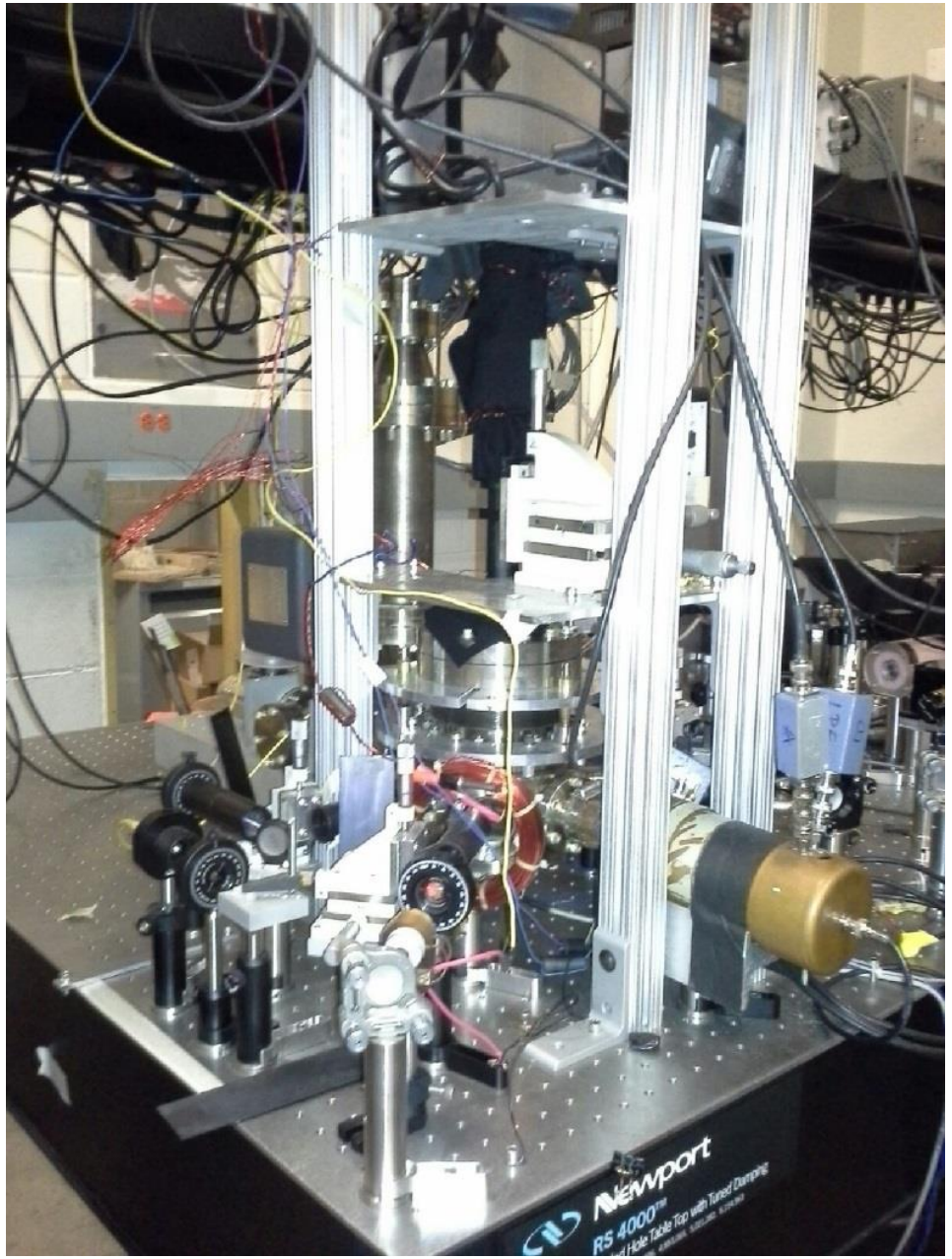
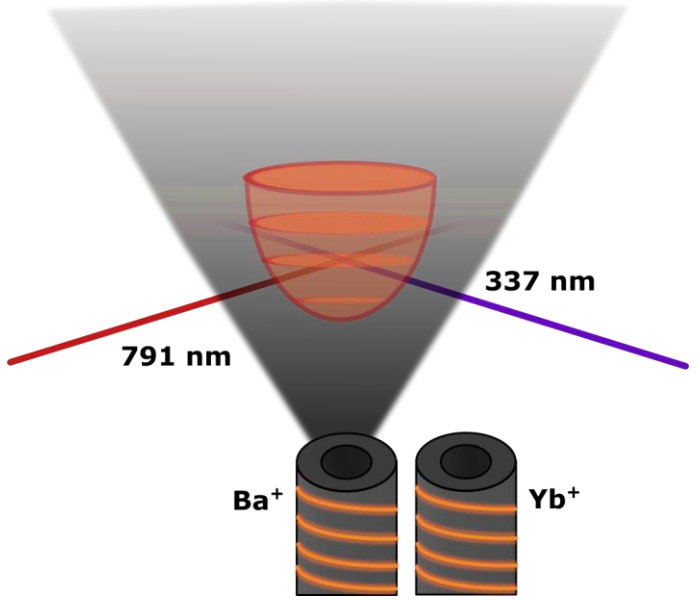
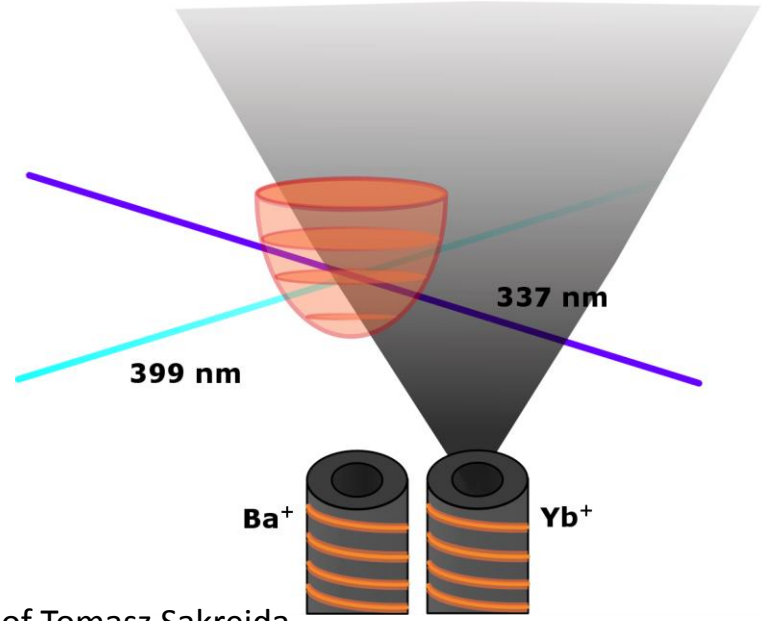


Barium-Ytterbium trapping

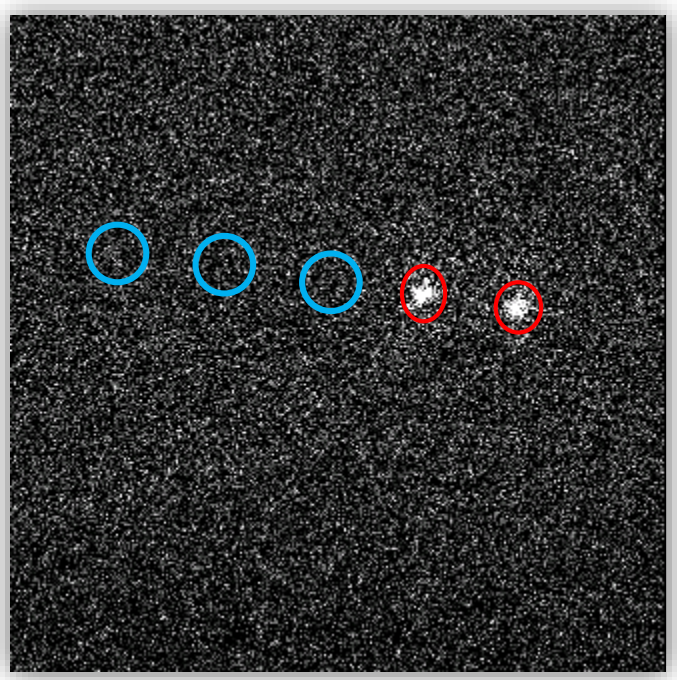
- First we trap and cool the barium ions
  (Doppler cooled with lasers)
- Then trap and cool ytterbium ions
  (sympathetically cooled by barium ions)
- 399nm laser issues
- Yb oven current issues

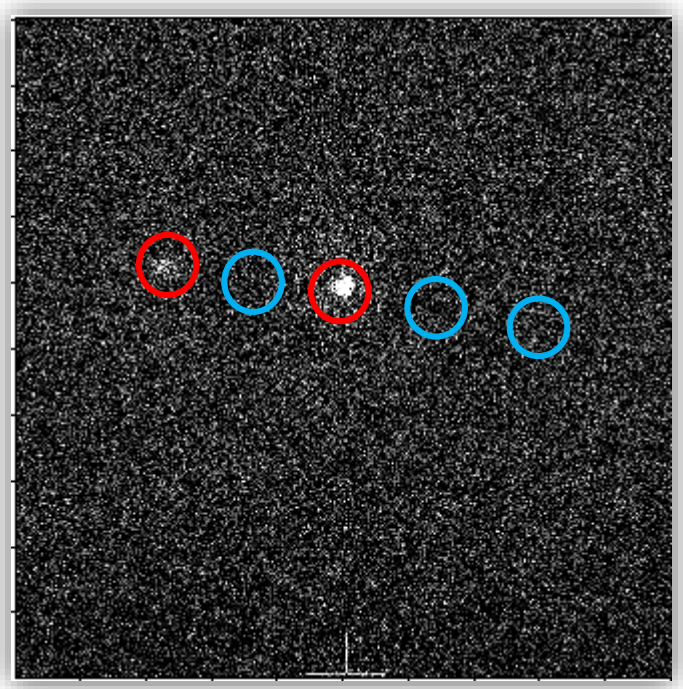


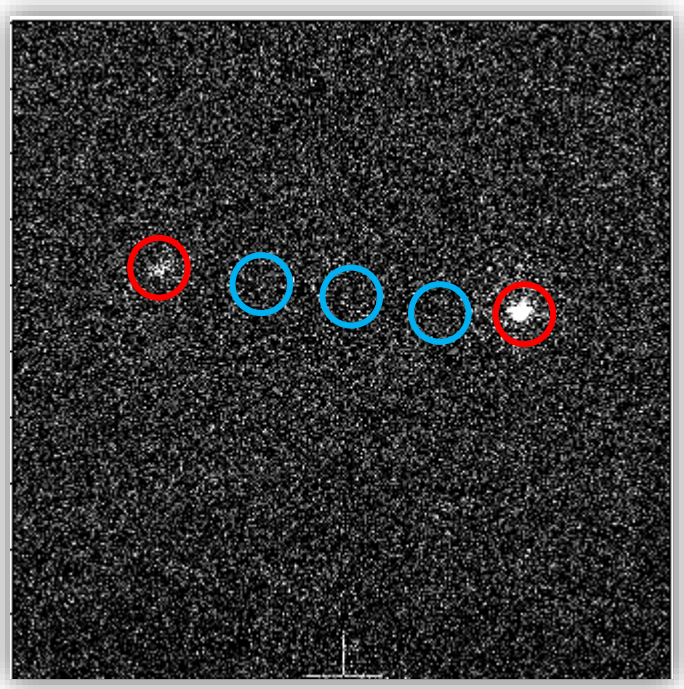


Photos courtesy of Tomasz Sakrejda

Ba-Yb Chains







Note: These were all taken in about a 15 minute time span

Micromotion

- Due to being off center of harmonic potential
- Hotter ions!
- Want micromotion sidebands amplitude to get smaller

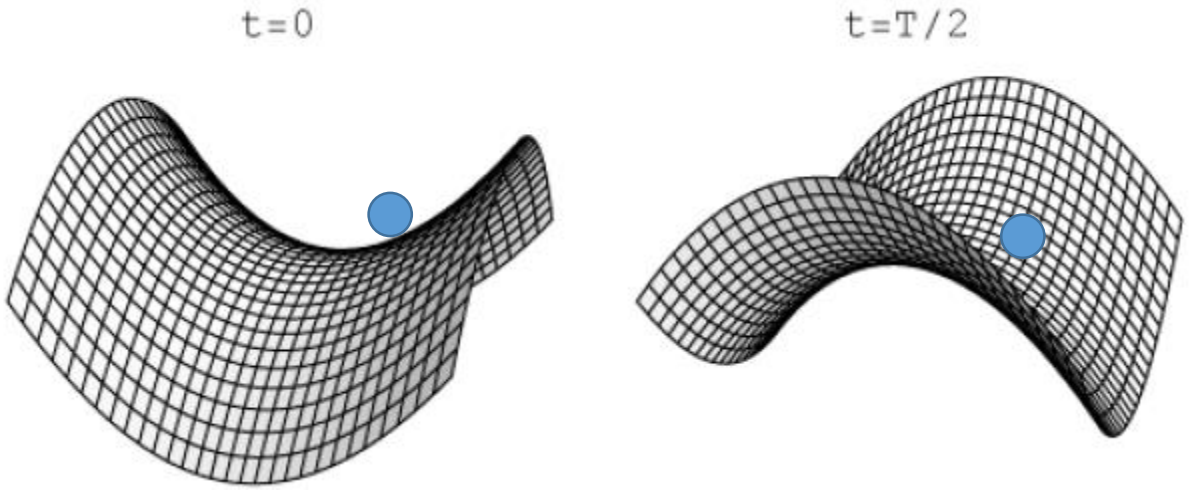


Photo courtesy of Mostafa on http://physics.stackexchange.com/questions/82291/quadrupole-potential-generation-in-paul-traps

Shelving

- Takes ion out of cooling cycle
- Shelve to $D_{\frac{5}{2}}$ state
- Deshelve back to cooling cycle using 614
- For measuring ion temperature and micromotion

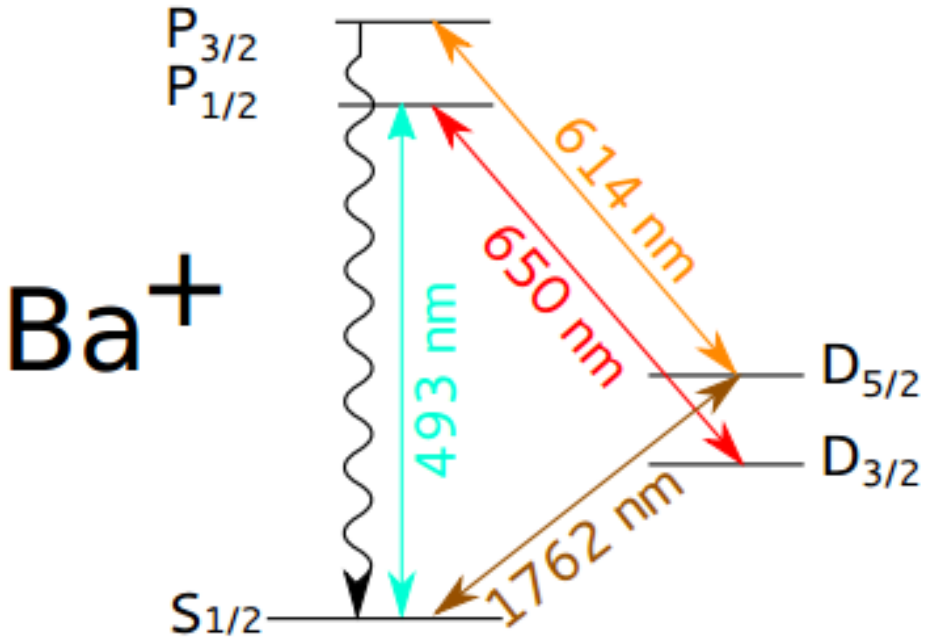


Photo courtesy of John Wright, et. al

Sideband scans

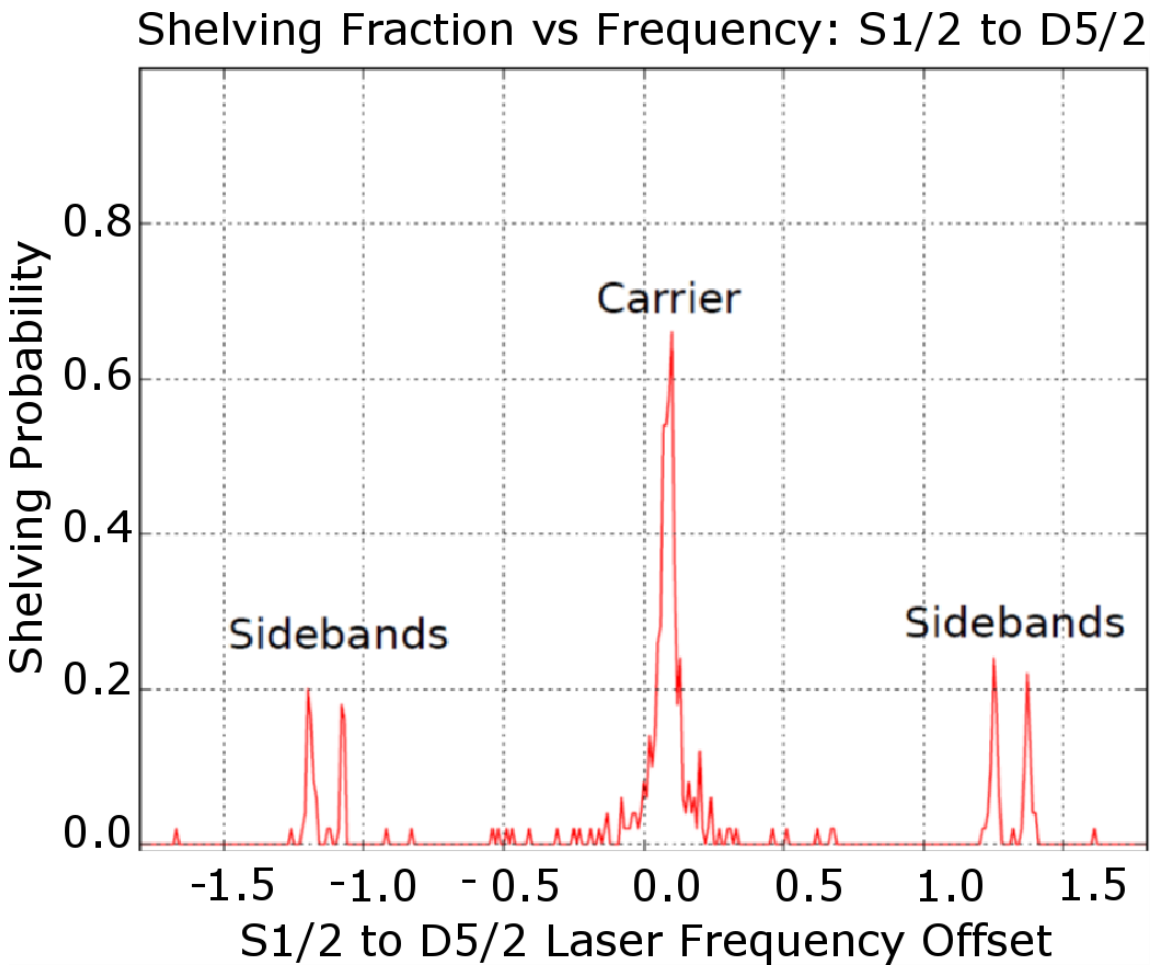


Photo courtesy of Tomasz Sakrejda

- Give information on temperature of the ion (indirectly)
- Relatively insensitive measurement to our laser noise

Compensating for micromotion

1. Visually
    - Ion movement

2. 1762 method
    - Shelving efficiency

- Compensation achieved through altering voltages

Recall our RF trap:

- DC offset on rods (independent of RF of rods)
- Offset on one grounded rod (blue) and another on one RF rod (red)

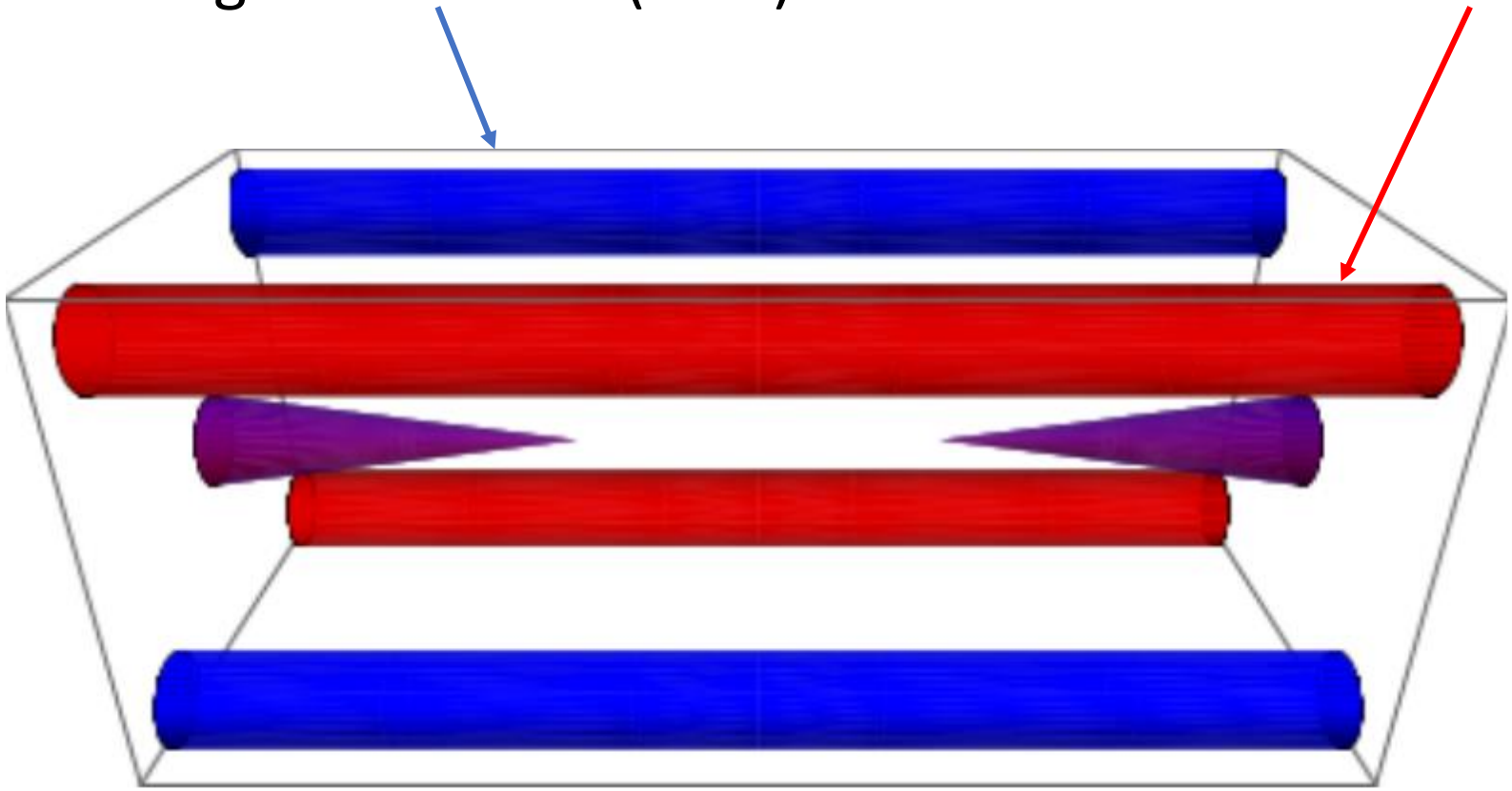
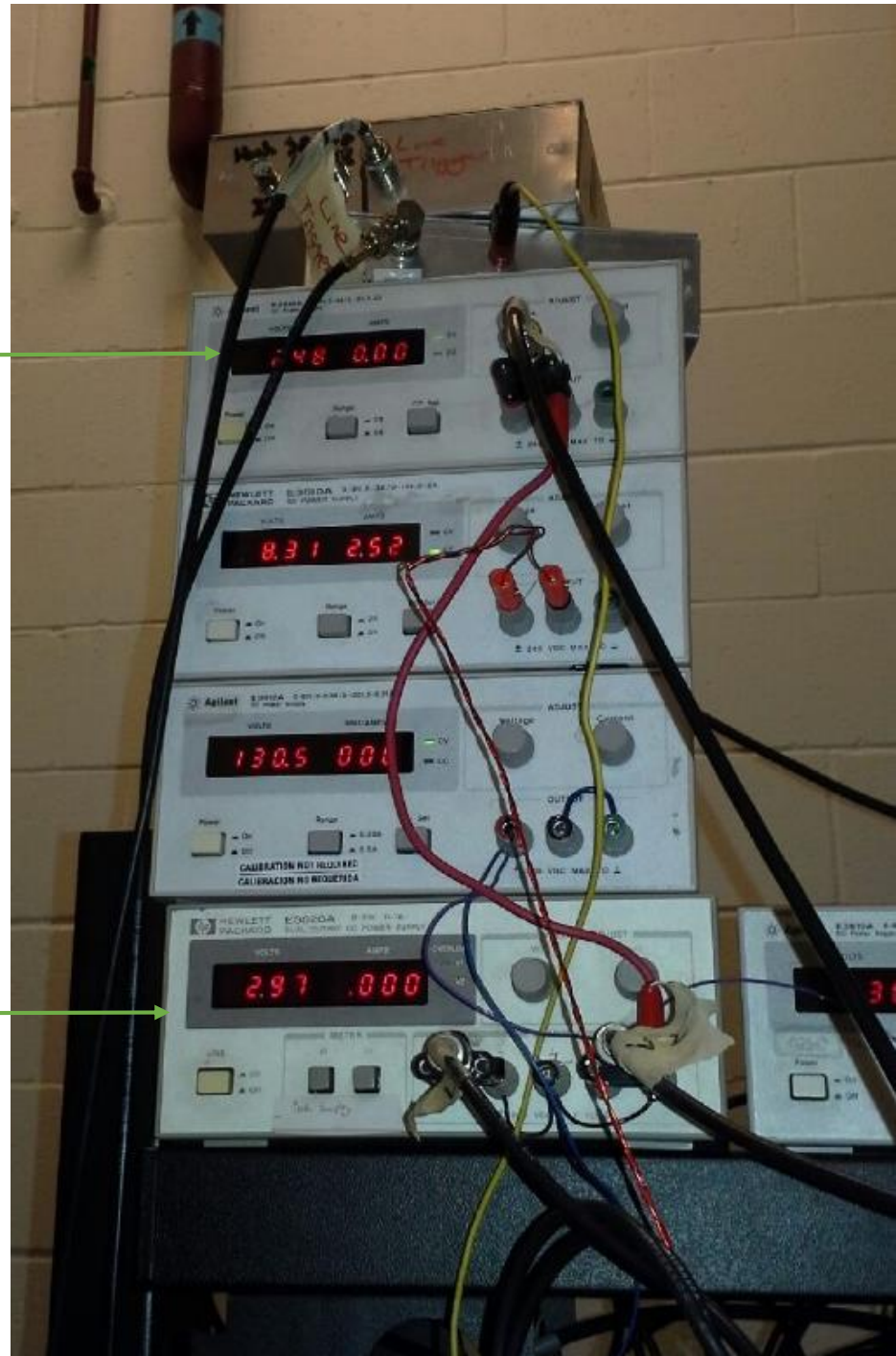


Photo courtesy of John Wright

TOWER OF POWER!



The top box controls one of the voltages, the bottom box controls the other.

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Finding carrier transition (again)

- The 1762 laser underwent some changes
- We lost the peak we usually lock to
- As of right now still in the process of finding it
- Want to find the same transition we've been using

Oh the places you'll go…

- Working on getting one qubit gates functional
- Then working on getting multiple qubit gates functional as well

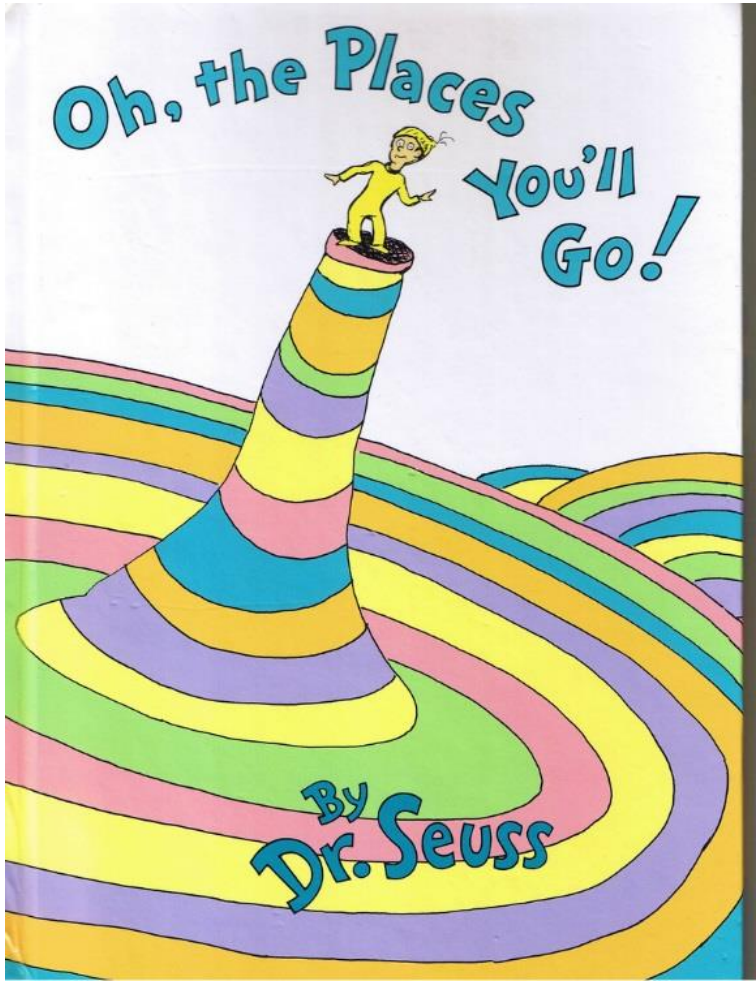

Photo courtesy of flickr.com

THANK YOU!

Boris Blinov, Tomasz Sakrejda, Spencer Williams, Carolyn Auchter and the rest of the groovy cats in the ion trapping group!

Linda Vilett, Farha Habib, Shih-Chih Hsu, Alejandro Garcia, Deep Gupta

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